4.0 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to determine COPC estimated exposure levels (EEL) for each measurement receptor. For community measurement receptors, the EEL is the estimated COPC concentration in soil, surface water, or sediment, depending on the receptor. For mammalian and avian measurement receptors, the EEL is the estimated COPC daily dose. Different EELs are used because the measure of effect (the TRV) for a community receptor is based on the COPC concentration in the medium, whereas the TRV for a mammalian or avian measurement receptor is reported in terms of daily dose ingested (U.S. EPA 1999).

The following sections outline the methods that will be used to determine (1) media concentrations, (2) ELs for community measurement receptors, and (3) EELs for mammalian and avian measurement receptors.

4.1 DETERMINATION OF MEDIA CONCENTRATIONS

Media concentrations will be calculated according to U.S. EPA (1999) procedures. Sections 4.1.1 through 4.1.3 present an overview of the methods for determining the media concentrations and the variables associated with these computations. COPC fate and transport parameter values are presented in Tables B-1 and B-2 in Appendix B. The parameter values for the COPCs in Table B-1 were taken from U.S. EPA (1999), while the parameter values for the chemical agents (Table B-2) were reported in the HHRA report (Tetra Tech 2002a).

4.1.1 Soil

U.S. EPA (1999) procedures will be used to quantify a COPC concentration in soil (Cs), which will be used as a COPC EEL for the terrestrial plant and soil invertebrate communities. As presented in Table C-1, Cs depend on the deposition term (Ds), the soil loss constant (ks), and the time period of combustion (tD). Table C-1 also presents the equation for calculating Ds. As presented in Table C-2, several process-specific loss constants are summed to calculate ks. The equations for calculating the loss constants for these processes are presented in Tables C-3 through C-6. Time period of combustion for TOCDF and CAMDS is discussed in Section 2.3. COPC-specific values for constants and parameters used to calculate Ds and ks are presented in Appendix B.

4.1.2 Surface Water

U.S. EPA (1999) procedures will be used to quantify the dissolved water COPC concentrations (C_{dw}) and the total water column COPC concentration (C_{wctot}) that will be used as COPC EELs, depending on the pathway and receptor. The calculation of C_{dw} is a complex process involving numerous variables, constants, physical and chemical parameters, and several water body characteristics. As presented in Table C-7, C_{dw} is a function of C_{wctot}, the total suspended solids concentration, and the partitioning of the COPC between the suspended solids and the water. The calculation of C_{wctot}, which is presented in Table C-8, depends on the total COPC load to the water body (L_T; Table C-9), the fraction of COPC in the water column (f_{wc}; Table C-10), the water body dissipation rate constant (k_{wt}; Table C-11), and several hydrological parameters that are specific to each water body, including volumetric flow rate, surface area, and depth of water column. L_T is the sum of the deposition load (L_{dep}; Table C-12), the diffusion load (L_{dif}; Table C-13), the impervious runoff load (L_{RI}; Table C-14), the pervious runoff load (L_R; Table C-15), and the erosion load (L_E; Table C-16). L_E depends on the unit soil loss (X_e; Table C-17) and the sediment delivery ratio (SD; Table C-18). k_{wt} depends on f_{wc}, the volatilization rate constant (k_v; Table C-19), the fraction of COPC in the bed sediment (f_{bs}; Table C-10), and the benthic burial rate constant (k_b; Table C-20). k_v depends on the overall COPC transfer rate coefficient (K_v; Table C-21) and water body characteristics. K_v is calculated from the liquid-phase transfer coefficient (K_L; Table C-22), the gas-phase transfer coefficient (KG; Table C-23), and several constants and water body characteristics.

COPC-specific parameter values used in the equations in Tables C-7 through C-23 are presented in Appendix B. Site-specific climatic parameters used in the HHRA (Tetra Tech 2002a) will be used in the Phase I ERA. The values for water body characteristics are presented in Table 4-1.

4.1.3 Bed Sediment

A COPC EEL for sediment receptors, which include rooted aquatic plants and benthic invertebrates, will correspond to the bed sediment COPC concentration (C_{sed}), which will be estimated using the equation presented in Table C-24 (U.S. EPA 1999). C_{sed} depends on the fraction of the COPC concentration in the sediment (Table C-10), the total water body concentration (C_{wtot}; Table C-25), several other variables, and water body characteristics. C_{wtot} depends on L_T (Table C-9), f_{wc} (Table C-10), k_{wt} (Table C-11), and

TABLE 4-1

WATER BODY CHARACTERISTICS

Water Body	Surface Area (m^2)	Average Depth (m)	Volume (m^3)	Volumetric Flow Rate (m^3/year)	Source
Atherly Reservoir	200,000	1.2	240,000	2,000,000	MRI 1998 [1]
Clover Pond	12,100	0.6	7,300	7,300	MRI 1998 [1]
Rainbow Reservoir	10,873 [2]	4.6	49,711 [2]	1,392,000	Tetra Tech 2002
Rush Lake	1,064,796 [2]	2	6,388,775 [2]	0	Tetra Tech 2002

Notes:

[1] Estimated values
[2] Values determined with IRAP-h View when determining COPC concentrations in water body

m	meter
m^2	square meter
m^3	cubic meter
MRI	Midwest Research Institute
Tetra Tech	Tetra Tech EM Inc.

water body characteristics. COPC-specific parameter values used in the equations in Tables C-10, C-24, and C-25 are presented in Appendix B. Water body-specific hydrological parameters are presented in Table 4-1.

4.2 DETERMINATION OF ESTIMATED EXPOSURE LEVELS FOR COMMUNITY MEASUREMENT RECEPTORS

EcoRisk View will be used to quantify an average soil COPC concentration for the shrub-scrub habitat, the montane habitat, and the watershed for each aquatic ecosystem. These soil concentrations will be used as the COPC EELs for the terrestrial plant and soil invertebrate communities or for calculating loading to a water body (Tetra Tech 2002c). Similarly, EcoRisk View will be used to determine average COPC concentrations in surface waters and sediments of evaluated water bodies that will be set as EELs for surface water and sediment communities.

C_{dw} will be used as the EEL for aquatic life, which includes communities like the phytoplankton, zooplankton, and fish. C_{dw} is used as the EEL because aquatic toxicity is caused mainly by the interaction of dissolved toxicants with sensitive external tissues (U.S. EPA 1999). C_{sed} will be used as the EEL for evaluating exposure for the benthic communities. Separate dissolved water and bed sediment concentrations will be determined for each water body (using EcoRisk View) because water body concentrations depend on direct deposition and watershed input (U.S. EPA 1999).

4.3 DETERMINATION OF ESTIMATED EXPOSURE LEVELS FOR MAMMALIAN AND AVIAN MEASUREMENT RECEPTORS

Exposure to a COPC by a mammalian or avian measurement receptor is quantified by estimating the daily COPC dose to the receptor. The dose includes uptake from both food and media (U.S. EPA 1999). The dose ingested (expressed as the mass of COPC ingested per kilogram body weight per day) depends on (1) the COPC concentration in plant and animal food items and in media ingested by the measurement receptor, (2) the TL of the measurement receptor, (3) the TLs of the animal food items, and (4) the measurement receptor's food and media ingestion rates. The following equation (U.S. EPA 1999) will be used to calculate daily dose:

$$DD = \sum IR_F \cdot C_i \cdot P_i \cdot F_i + \sum IR_M \cdot C_M \cdot P_M$$

where

DD = Daily dose of COPC ingested (mg COPC/kg body weight [BW]-day)

IR_F = Measurement receptor plant or animal food item ingestion rate (kg/kg BW-day)

C_i = COPC concentration in *i*th plant or animal food item (mg COPC/kg)

P_i = Proportion of *i*th food item that is contaminated (unitless)

F_i = Fraction of diet consisting of plant or animal food item *i* (unitless)

IR_M = Measurement receptor media ingestion rate (kg/kg BW-day [soil or bed Sediment] or L/kg BW-day [water])

C_M = COPC concentration in media (mg/kg [soil or bed sediment] or mg/L [water])

P_M= Proportion of ingested media that is contaminated (unitless)

The media concentrations that will be used as EELs to assess direct and indirect exposure by mammalian and avian measurement receptors are as follows:

- **Direct and Indirect Soil Exposure**. Cs values based on the highest average air concentration and wet and dry deposition rates, calculated specific to montane and shrub-scrub soils, will be used to determine direct and indirect EELs in soil for mammalian and avian measurement receptors in these upland habitats. Cs values for watersheds will be calculated similarly.

- **Direct Water and Sediment Exposure**. EcoRisk View will be used to determine average COPC concentrations in surface waters and sediment of water bodies under evaluation. C_{wctot} and C_{sed} estimated for Clover Reservoir (BLM ponds) west of TOCDF and CAMDS (within property DCD property boundary), will be used to quantify the direct uptake of a COPC in water ingested by mammalian and avian measurement receptors with these exposure routes. Clover Reservoir was selected because it is the closest water body to the emissions sources and the results of the HHRA (Tetra Tech 2002a) indicate the highest depositions of COPCs are north and west of TOCDF and CAMDS. In addition, the majority of surface water at DCD that does not discharge to the ground water or evaporate flows into Clover Reservoir (Tetra Tech 2000).

- **Indirect Water and Sediment Exposure**. EcoRisk View will be used to determine average COPC concentrations in surface waters and sediment of water bodies under evaluation. C_{dw} and C_{sed}, estimated for each water body evaluated in the Phase I ERA, will be used to assess indirect (food chain) exposure by mammalian and avian measurement receptors in the aquatic food web. For example, C_{dw} will be used to estimate a COPC concentration in a fish ingested by a piscivorous bird, and C_{sed} will be used to estimate a COPC concentration in benthic invertebrates.

Exposure assessment procedures for mammalian and avian feeding guilds presented in the following sections conform to U.S. EPA (1999) procedures. Both “equal” diet and “exclusive” diet exposure assessments will be conducted for mammals and birds evaluated in the Phase I ERA.

4.3.1 Determination of COPC Concentrations in Media Ingested by Mammals and Birds

The COPC daily dose ingested by a measurement receptor depends, in part, on the COPC concentration in media ingested by the receptor. A COPC concentration in ingested media will be calculated using the equations and parameter values discussed in Section 4.1 and presented in Appendix C. The media EELs to assess direct exposure by mammalian and avian measurement receptors include Cs, C_{wctot}, and C_{sed}, as described above.

4.3.2 Determination of COPC Concentrations in Food Items Ingested by Mammals and Birds

The problem formulation presented the habitat food webs that will be used as the framework for the exposure assessment. The food webs include numerous food chain interactions involving the consumption of TL1 plants and TL2 and TL3 animals by TL2, TL3, and TL4 measurement receptors. To estimate the dietary dose of a COPC, the COPC concentrations in ingested plants and animals must be estimated. To meet this objective, several models recommended in the U.S. EPA (1999) *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (SLERAP) will be used. The specific model used will depend on the receptor, the type of food item, and the tropic level of the food item.

As presented in U.S. EPA (1999), COPC concentrations in food items will be calculated using bioconcentration factors (BCF) and food chain multipliers (FCM). The identification of COPC-specific BCF values for estimating COPC concentrations in ingested plants and animals is discussed in the following sections. In accordance with U.S. EPA (1999) recommendations, if a BCF is not available for an inorganic COPC or cannot be estimated using any of the regression models presented in U.S. EPA (1999), a BCF of 1.0 will be assumed. These procedures will ensure that indirect exposure is evaluated for each COPC for each measurement receptor.

4.3.2.1 Trophic Level 1 and 2 Food Items

TL1 plants and TL2 invertebrates and fish are in intimate contact with soil, surface water, or sediment. Thus, a COPC concentration in these receptors can be estimated by multiplying a medium-specific COPC concentration by a medium-to-receptor BCF (U.S. EPA 1999), as follows:

$$C_i = C_M \cdot BCF$$

where

C_i	=	COPC concentration in the ith plant or animal food item (milligram per kilogram [mg/kg])
C_M	=	COPC concentration in media (mg/kg or milligram per liter [mg/L])
BCF	=	Bioconcentration factor (unitless)

The expression above will be used to determine COPC concentrations specific to each food item. For estimating the food item concentration of a COPC listed in U.S. EPA (1999), the receptor-specific BCF values recommended in the SLERAP will be used. For COPCs identified from the ANCDF ERA protocol (see Section 2.4), corresponding water-to-fish BCF values from the ANCDF ERA protocol were adopted for the fish pathways that will be evaluated in the TOCDF Phase I ERA. A review of these BCF values indicated they were developed in accordance with U.S. EPA (1999). If a BCF value was not available in the ANCDF ERA protocol, BCF values for each food item were calculated according to U.S. EPA (1999) procedures. Likewise, BCF values for GB, VX, and sulfur mustard were also calculated according to U.S. EPA (1999) procedures. The media-to-receptor BCF values and basis of the values are presented in Appendix D-3.

The following sections discuss the methods used to determine the COPC concentrations in ingested food items for COPCs not listed in U.S. EPA (1999). These COPCs are listed in Section 2.4.

Terrestrial Plants

The COPC concentration in terrestrial plants will be determined by calculating the plant concentration due to direct deposition (Pd), air-to-leaf transfer (Pv), and root uptake (Pr).

$$C_{TP} \quad = \quad Pd + Pv + (Pr \cdot 0.12)$$

where

C_{TP}	=	COPC concentration in terrestrial plants (mg/kg wet weight [WW])
Pd	=	COPC concentration in plant due to direct deposition (mg/kg WW)
Pv	=	COPC concentration in plant due to air-to-plant transfer (mg/kg WW)
Pr	=	COPC concentration in plant due to root uptake (mg/kg dry weight [DW])
0.12	=	DW-to-WW conversion factor

As presented in Table C-26, Pd depends on the COPC emission rate (Q), the fraction of COPC air concentration in the vapor phase (F_v), the fraction of the edible portion of the plant, the fraction of deposited COPC that adheres to the plant surface, and the exposure time. Pv mainly depends on Q, F_v, and the air-to-plant biotransfer factor (Table C-27). As presented in Table C-28, Pr depends on Cs and the soil-to-plant BCF, which is discussed below.

Soil-to-Plant and Sediment-to-Plant Bioconcentration Factors

As recommended in U.S. EPA (1999), a regression equation from Travis and Arms (1988) was used to calculate soil-to-plant and sediment-to-plant BCFs for the organic COPCs, including the three agents:

$$\log BCF = 1.588 - 0.578 \log K_{ow}$$

A BCF for boron is not available; thus, a value of 1.0 will be used to estimate the bioconcentration potential of the COPC in food items, as recommended in U.S. EPA (1999).

Soil-to-Soil Invertebrates, Sediment-to-Sediment Invertebrates, Water-to-Aquatic Invertebrates, and Water-to-Algae Bioconcentration Factors

For organic COPCs, the soil-to-soil invertebrate, sediment-to-sediment invertebrate, water-to-aquatic invertebrate, and water-to-algae BCF values were estimated using the following regression equation provided by Southworth and others (1978):

$$\log BCF = 0.819 \cdot \log K_{ow} - 1.146$$

In accordance with U.S. EPA (1999) procedures, soil-to-invertebrate, sediment-to-sediment invertebrate, water-to-aquatic invertebrate, and water-to-algae BCFs for boron were set equal to the arithmetic average of the BCF values for other inorganics listed in U.S EPA (1999).

Water-to-Fish Bioconcentration Factors

For organic COPCs, water-to-fish BCF values were estimated using the following regression equation provided by Veith and others (1980):

$$\log BCF = 0.76 \cdot \log K_{ow} - 0.23$$

Consistent with U.S. EPA (1999) guidance, the water-to-fish BCF for boron was set equal to the arithmetic average of the BCF values for inorganics listed in the SLERAP.

4.3.2.2 Trophic Level 3 and 4 Fish

To estimate a COPC concentration in TL3 and TL4 fish, an FCM will be applied to the water-to-fish BCF discussed in Section 4.2.2.1, as shown in the following expression:

$$C_F = BCF \cdot FCM \cdot C_{dw}$$

where

C_F=COPC concentration in fish (mg/kg)
BCF=Bioconcentration factor (unitless)
FCM=Food chain multiplier (unitless)
C_{dw}=Dissolved water COPC concentration (mg/L)

FCM values depend on the trophic level. The FCM values listed in the SLERAP (U.S. EPA 1999) will be used for the above expression.

4.3.2.3 Herbivorous Birds and Mammals

The COPC concentration in herbivorous mammals and birds will be calculated by summing the contribution from the ingestion of contaminated plant food items and the contribution from the ingestion of contaminated media. The U.S. EPA (1999) equation for computing COPC concentrations in herbivores is as follows:

$$C_H = \sum \left(C_{Pi} \cdot BCF_{Pi-H} \cdot P_{Pi} \cdot F_{Pi}\right) + \left(C_{s/sed} \cdot BCF_{S/BS-H} \cdot P_{S/BS}\right) + \left(C_{wctot} \cdot BCF_{W-H} \cdot P_W\right)$$

where

C_H	=	COPC concentration in herbivore (mg/kg)
C_{Pi}	=	COPC concentration in ith plant food item (mg/kg)
BCF_{Pi-H}	=	Bioconcentration factor for the plant-to-herbivore for ith plant food item (unitless)
P_{Pi}	=	Proportion of ith plant food item in diet that is contaminated (assumed to be 1, unitless)
F_{Pi}	=	Fraction of diet consisting of ith plant food item (receptor-specific, unitless)
$C_{s/sed}$	=	COPC concentration in soil or bed sediment (mg/kg)
$BCF_{S/BS-H}$	=	Bioconcentration factor for soil-to-plant or bed sediment-to-plant (unitless)
$P_{S/BS}$	=	Proportion of soil or bed sediment in diet that is contaminated (assumed to be 1, unitless)
C_{wctot}	=	COPC concentration (total) in water column (mg/L)
BCF_{W-H}	=	Bioconcentration factor for water-to-herbivore (liter per kilogram [L/kg])
P_W	=	Proportion of water in diet that is contaminated (assumed to be 1, unitless)

For measurement receptors ingesting more than one plant or animal food item, EPA (1999) recommends that exposure be separately quantified assuming that the measurement receptor ingests both “equal” and “exclusive” diets. An “equal” diet exposure assessment assumes that each food item is ingested in the same proportion. F_{Pi} will be calculated for each food item by dividing the total number of food items ingested into 1. For example, $F_i = 0.25$ for a measurement receptor that ingests four food items. Under the “exclusive” diet exposure scenario, the daily dose of COPC ingested is calculated assuming that the fraction of daily diet consumed by the measurement receptor is exclusively (100 percent) one food item group. For example, Fi = 1.0 for each food item group at a time, while the Fi values for the remaining food item groups are set equal to zero. The food item designated as exclusive is alternated to each respective food item represented in the COPC dose equation to obtain a range of exposure values based on exclusive diets. The evaluation of both "equal" and "exclusive" diet scenarios provides the most complete evaluation of exposure potential for a measurement receptor and, if necessary, identifies dietary pathways that are driving risk specific to a COPC and measurement receptor (EPA 1999). For herbivores that eat more than one plant item (such as emergent aquatic vegetation and riparian vegetation), exposure will be estimated assuming that the measurement receptor ingests both "equal" and "exclusive" diets.

4.3.2.4 Plant and Media Bioconcentration Factors for Measurement Receptor Prey

As depicted in the equation above for calculating a COPC concentration in an herbivorous prey item, BCFs are applied to the ingestion of plant matter and media pathways (U.S. EPA 1999). These BCFs are both COPC- and measurement receptor-specific. For an organic COPC, an expression by Travis and Arms (1988), based on the compound's log K_{ow} value, is used to calculate a COPC-specific biotransfer factor (Ba). U.S. EPA (1999) multiplies Ba by the plant or media ingestion rate, specific to each mammalian and avian measurement receptor, to determine receptor-specific plant and media BCFs. To determine BCFs for inorganic COPCs, U.S. EPA (1999) multiplies the measurement receptor plant or media ingestion rate by Ba values from existing sources cited in the SLERAP.

$$BCF = Ba \cdot IR$$

where

BCF=Plant, soil, water, or sediment bioconcentration factor (unitless)
Ba=Mammal or bird biotransfer factor (day/kg fresh weight [FW] tissue)
IR=Plant, soil, water, or sediment ingestion rate, specific to each measurement receptor (kg FW/day for plants; kg WW or DW/day for media)

Measurement receptor-specific plant and media BCF values for all COPCs were calculated as described above and are presented in Appendix D. The plant BCF values are also applied to the plant pathway for omnivorous food items, and the media BCFs are also applied to the media pathways for omnivorous and carnivorous food items (described below).

4.3.2.5 Omnivorous Mammals and Birds

The COPC concentration in omnivorous mammals and birds will be calculated by summing the contribution due to ingestion of contaminated animal food items, the ingestion of plant food items, and the ingestion of contaminated media. However, unlike herbivores (which are TL2 consumers), omnivores are TL3 consumers of animal food items. Thus, an FCM is applied to each animal food item ingested in order to account for the bioaccumulation of COPCs in predator species. The COPC concentration in omnivores depends on the COPC concentration in each food item ingested and the TL of each food item, as follows:

$$C_{OM} = \sum\left(C_{Ai} \cdot \frac{FCM_{TL3}}{FCM_{TLn-Ai}} \cdot P_{Ai} \cdot F_{Ai}\right) + \left(C_{Pi} \cdot BCF_{Pi-OM} \cdot P_{Pi}\ F_{Pi}\right) + \left(C_{s/sed} \cdot BCF_{S/BS-OM} \cdot P_{S/BS}\right) + \left(C_{wctot} \cdot BCF_{W-OM} \cdot P_{W}\right)$$

where

C_{OM}	=	COPC concentration in omnivore (mg/kg)
C_{Ai}	=	COPC concentration in ith animal food item (mg/kg)
FCM_{TL3}	=	Food chain multiplier for trophic level 3 (unitless)
FCM_{TLn-Ai}	=	Food chain multiplier for trophic level of ith animal food item (unitless)
P_{Ai}	=	Proportion of ith animal food item that is contaminated (assumed to be 1, unitless)
F_{Ai}	=	Fraction of diet consisting of ith animal food item (receptor-specific, unitless)
BCF_{Pi-OM}	=	Bioconcentration factor for the plant-to-omnivore for ith plant food item (unitless)
C_{Pi}	=	COPC concentration in ith plant food item (mg/kg)
P_{Pi}	=	Proportion of ith plant food item in diet that is contaminated (assumed to be 1, unitless)
F_{Pi}	=	Fraction of diet consisting of ith plant food item (receptor-specific, unitless)
$C_{s/sed}$	=	COPC concentration in soil or bed sediment (mg/kg)
$BCF_{S/BS-OM}$	=	Bioconcentration factor for soil- or bed sediment-to-omnivore (unitless)
$P_{S/BS}$	=	Proportion of soil or bed sediment in diet that is contaminated (assumed to be 1, unitless)
C_{wctot}	=	COPC concentration (total) in water column (mg/L)
BCF_{W-OM}	=	Bioconcentration factor for water-to-omnivore (L/kg)
P_{W}	=	Proportion of water in diet that is contaminated (assumed to be 1, unitless)

Exposure for omnivores will be estimated assuming both “equal” and “exclusive” diets . An FCM ratio will be used to estimate the increase in a COPC concentration resulting from the ingestion of TL2 prey (i.e., animal food item) by a TL3 measurement receptor (i.e., herbivore to omnivore), and the ingestion of TL2 and TL3 prey by a TL4 measurement receptor (U.S. EPA 1999). Biomagnification, expressed as a biomagnification factor (BMF), equals the quotient of the FCM of the measurement receptor divided by the FCM of the prey. It is important to note that the basic difference between the FCM and BMF is that the an FCM relates back to TL1, whereas a BMF relates back to the preceding TL, as demonstrated by the following equation:

$$BMF_{TL3} = \frac{FCM_{TL3}}{FCM_{TL2}}$$

where

BMF_{TL3}=Biomagnification factor for trophic level 3 (unitless)
FCM_{TL3}=Food chain multiplier for trophic level 3 (unitless)
FCM_{TL2}=Food chain multiplier for trophic level 2 (unitless)

4.3.2.6 Carnivorous Mammals and Birds

The COPC concentration in carnivorous mammals and birds will be calculated by summing the contribution due to ingestion of contaminated animal and media food items. A ratio of FCMs is applied to each animal food item ingested to account for the increase in COPC concentration occurring between the TL of the prey item (TLn) and the TL of the carnivore (TL4). The COPC concentration in carnivores depends on the COPC concentration in media, in each animal food item ingested, and their respective TL, as follows:

$$C_{CM} = \sum\left(C_{Ai} \cdot \frac{FCM_{TL4}}{FCM_{TLn-Ai}} \cdot P_{Ai} \cdot F_{Ai}\right) + \left(C_{s/sed} \cdot BCF_{S/BS-CM} \cdot P_{S/BS}\right) + \left(C_{wctot} \cdot BCF_{W-CM} \cdot P_{W}\right)$$

where

C_{CM}	=	COPC concentration in carnivore (mg/kg)
C_{Ai}	=	COPC concentration in ith animal food item (mg/kg)
FCM_{TL4}	=	Food chain multiplier for trophic level 4 (unitless)
$FCM_{TLn\text{-}Ai}$	=	Food chain multiplier for trophic level of ith animal food item (unitless)
P_{Ai}	=	Proportion of ith animal food item that is contaminated (assumed to be 1, unitless)
F_{Ai}	=	Fraction of diet consisting of ith animal food item (receptor-specific, unitless)

$C_{s/sed}$	=	COPC concentration in soil or bed sediment (mg/kg)
$BCF_{S/BS-CM}$	=	Bioconcentration factor for soil- or bed sediment-to-carnivore (unitless)
$P_{S/BS}$	=	Proportion of soil or bed sediment in diet that is contaminated (assumed to be 1, unitless)
C_{wctot}	=	COPC concentration (total) in water column (mg/L)
BCF_{W-CM}	=	Bioconcentration factor for water-to-carnivore (L/kg)
P_W	=	Proportion of water in diet that is contaminated (assumed to be 1, unitless)

Exposure for carnivorous receptors will be estimated assuming both "equal" and "exclusive" diets. The use of an FCM ratio to estimate biomagnification between trophic levels is discussed in the preceding subsection.

4.3.3 Natural History Information

This section describes the receptor-specific terms of the daily dose equation and the receptor-specific values that will be applied in the risk assessment. Section 4.3.3.1 describes methods for estimating the receptor-specific rates of COPC ingestion through the ingestion of contaminated food items and/or media. Section 4.3.3.2 presents receptor-specific natural history information obtained from available literature.

4.3.3.1 Food and Media Ingestion

Food ingestion rates were determined using allometric equations developed by Nagy (1987), as presented in the *Wildlife Exposure Factors Handbook* (U.S. EPA 1993). The allometric equations are based on metabolic rate information estimated from measurements of carbon dioxide production in free-living animals. The lowest body weight identified in literature was selected as the representative body weight for each measurement receptor. The lowest available value was selected so that a higher, more protective ingestion rate would be calculated. The ranges of body weight values identified in available literature for each mammalian and avian measurement receptor are presented in Appendix D.

Food ingestion rates (FIR) are reported as kilograms wet weight/kilograms body weight-day (kg WW/kg BW-day). The allometric equations developed by Nagy 1987, as presented in U.S. EPA (1993), provide DW food ingestion rates. DW food ingestion rates were converted to WW by considering the estimated percent moisture in the organism's diet, as follows:

$$\mathrm{FIR}_{\mathrm{WW}} = \frac{FIR_{DW}}{\left[\frac{(100 - \%\ moisture)}{100}\right]}$$

where

$\mathrm{FIR}_{\mathrm{WW}}$	=	Food ingestion rate in wet weight (kg WW/day)
$\mathrm{FIR}_{\mathrm{DW}}$	=	Food ingestion rate in dry weight f (kg DW/day)
% moisture	=	Percent moisture in animal's diet (herbivores, 88%; omnivores, 78%; carnivores, 68% [U.S. EPA 1999])

Wet weight FIRs were divided by the representative BW (kg) of the receptor. The resulting receptor-specific food ingestion rates are expressed as kg WW/kg BW-day.

Water ingestion rates (WIR), expressed as liters/kilograms BW-day (L/kg BW-day), were also calculated using allometric equations developed by Nagy (1987), presented in U.S. EPA (1993). The soil/sediment ingestion rates (SIR) were calculated as a percentage of the receptor's $\mathrm{FIR}_{\mathrm{DW}}$ that is soil or sediment; the values are reported as kg dry weight/kg body weight-day (kg DW/kg BW-day). This value is receptor-specific. If information on the soil or sediment content in a receptor's diet was unavailable, information for a suitable surrogate was used.

Food and Media Ingestion Rates for Avian Measurement Receptors

$\mathrm{FIR}_{\mathrm{DW}}$ values for avian measurement receptors were calculated using two equations presented in U.S. EPA (1993). For the American robin, a passerine, an $\mathrm{FIR}_{\mathrm{DW}}$ was calculated with the following equation:

$$\mathrm{FIR}_{\mathrm{DW}} = 0.398 \cdot \mathrm{BW}^{0.850}$$

where

$\mathrm{FIR}_{\mathrm{DW}}$	=	Dry weight food ingestion rate (grams [g] DW/day)
BW	=	Body weight (g)

$\mathrm{FIR}_{\mathrm{DW}}$ values for other birds were calculated using the following equation:

$$FIR_{DW} = 0.0582 \cdot BW^{0.651}$$

where

FIR_{DW}	=	Food ingestion rate (g DW/day)
BW	=	Body weight (g)

FIR_{WW} values were determined by dividing a FIR_{DW} value by the receptor BW value.

WIR values for the avian receptors were calculated using the following generic equation for all bird species (U.S. EPA 1993).

$$WIR = 0.59 \cdot BW^{0.67}$$

where

WIR	=	Water ingestion rate (L/day)
BW	=	Body weight (kg)

Soil and sediment ingestion rates for avian receptors were calculated from available species-specific information based on percent soil in the diet. If species-specific information was not available, information from a surrogate receptor was used.

Food and Media Ingestion Rates for Mammalian Measurement Receptors

FIRs for mammalian receptors were calculated using three allometric equations developed by Nagy (1987). FIR_{DW} values for herbivores, which include the pronghorn antelope and the elk, were calculated using the following equation:

$$FIR_{DW} = 0.577 \cdot BW^{0.727}$$

where

FIR_{DW}	=	Food ingestion rate (g DW/day)
BW	=	Body weight (g)

The FIR_{DW} value for the deer mouse, a rodent, was calculated as follows:

$$FIR_{DW} \quad = \quad 0.621 \cdot BW^{0.564}$$

where

FIR_{DW}	=	Food ingestion rate (g DW/day)
BW	=	Body weight (g)

For the muskrat and coyote, food ingestion rates were calculated as follows:

$$FIR_{DW} \quad = \quad 0.0687 \cdot BW^{0.822}$$

where

FIR_{DW}	=	Food ingestion rate (g DW/day)
BW	=	Body weight (g)

FIR_{WW} values were calculated by dividing FIR_{DW} values by receptor body weight.

WIR values for mammalian receptors were calculated using the following generic equation for all mammalian species (U.S. EPA 1993).

$$WIR \quad = \quad 0.099 \cdot BW^{0.9}$$

where

WIR	=	Water ingestion rate (L/day)
BW	=	Body weight (kg)

Soil and sediment ingestion rates for avian receptors were calculated from available species-specific information based on percent soil in the diet. Soil and sediment ingestion rates, which are reported in terms of kg DW/kg BW-d, were calculated from FIR_{DW} values. If species-specific information was not available, information from a surrogate receptor was used.

4.3.3.2 Receptor-Specific Natural History Information

Receptor-specific natural history information obtained from available literature is presented in this section for each mammalian and avian measurement receptor in each food web. Individual receptors are addressed within their respective guilds. Table 4-2 summarizes the receptor natural history information.

Shrub-Scrub Food Web

The natural history information and values that will be used to calculate a COPC daily dose for each shrub-scrub measurement receptor are discussed below.

Herbivorous Mammals

The species selected as the measurement receptor for this guild is the pronghorn antelope (*Antilocarpa americana*). Pronghorn antelope prefer browse and forbs as food items (Hoover 1966). Sagebrush, a dominant plant species in Rush Valley, is a commonly selected food item (Bayless 1969). Coyote, bobcat, mountain lions, and golden eagles are important predators of the pronghorn antelope, with the bobcat, coyote, and golden eagle feeding mainly on fawns, especially newborns (Yoakum 1980; Goodwin 1976; FEIS 1996; Reichel 1991; Ockenfels 1994).

The COPC daily dose for the pronghorn antelope will be estimated in the ERA assuming that 100 percent of its diet is terrestrial plants (F_{Pi} = 1.0).

Pronghorn range in weight from 34 kg to 64 kg (AMNH 2000; NGPC 2000). The FIR calculated was 0.28kg WW/kg BW-d, and the WIR calculated was 0.070 L/kg BW-d (Nagy 1987). An SIR equal to 0.0018 kg DW /kg BW -d was calculated based on the estimate that soil comprises 5.4 percent of the antelope's daily food intake (Arthur and Gates 1988).

TABLE 4-2

SUMMARY OF NATURAL HISTORY INFORMATION FOR MAMMALIAN AND AVIAN MEASUREMENT RECEPTORS

	Measurement Receptor (*Scientific name*)	BW (g)	Food IR[c] (kg WW/kg BW/day)	No. of Food Items	Water IR[c] (L/kg BW/day)	Soil/Sediment IR (kg DW/ kg BW/day)
Shrub-Scrub Food Web						
Herbivorous mammal	Pronghorn antelope (*Antilocarpa americana*)	34,000 [a]	0.28	1	0.070	0.0018 [h]
Herbivorous bird	Sage grouse (*Centrocercus urophasianus*)	1,600 [b]	0.41	1	0.051	0.0046 [i]
Omnivorous mammal	Deer mouse (*Peromyscus maniculatus*)	14.8 [c]	0.87	2	0.151	0.00405 [i]
Omnivorous bird	American robin (*Turdus migratorius*)	80 [j]	0.94	2	0.137	0.0213 [i,j]
Carnivorous mammal	Coyote (*Canis lantrans*)	10,000 [d]	0.14	4	0.079	0.0037 [i]
Carnivorous bird	Red-tailed hawk (*Buteo jamaicensis*)	960 [c]	0.18	5	0.060	0.00078 [j]
Montane Food Web						
Herbivorous mammal	Elk (*Cervus elaphus*)	236,000 [e]	0.16	1	0.057	0.00039 [i]
Herbivorous bird	Blue grouse (*Dendragapus obscurus*)	1, 273 [f]	0.45	1	0.054	0.0049 [i]
Omnivorous mammal	Deer mouse (*Peromyscus maniculatus*)	14.8 [c]	0.87	2	0.151	0.00405 [i]
Omnivorous bird	Chukar (*Alectoris chukar*)	600 [f]	0.32	2	0.070	0.0070 [i,j]
Carnivorous mammal	Coyote (*Canis lantrans*)	10,000 [d]	0.14	4	0.079	0.00037 [i,j]
Carnivorous bird	Red-tailed hawk (*Buteo jamaicensis*)	960 [c]	0.18	5	0.060	0.00078 [j]
Aquatic Food Web						
Herbivorous bird	Northern pintail (*Anas acuta*)	900 [g]	0.50	1	0.061	0.0012 [i]
Omnivorous mammal	Muskrat (*Ondatra zibethicus*)	830 [g]	0.32	2	0.101	0.00193 [i]
Omnivorous aquatic bird	Mallard (*Anas platyrhynchos*)	1,040[j]	0.26	2	0.058	0.0019 [i]
Piscivorous bird	Great blue heron (*Ardea herodias*)	2,200 [g]	0.14	2	0.045	0.00078 [i,j]
Carnivorous mammal	Coyote (*Canis lantrans*)	10,000 [d]	0.14	3	0.079	0.00037 [i,j]
Carnivorous bird	Red-tailed hawk (*Buteo jamaicensis*)	960 [c]	0.18	4	0.060	0.00078 [j]

TABLE 4-2 (Continued)

SUMMARY OF NATURAL HISTORY INFORMATION FOR MAMMALIAN AND AVIAN MEASUREMENT RECEPTORS

Notes:

BW	Body weight
DW	Dry weight
IR	Ingestion rate
k	Kilogram
L	Liter
WW	Wet weight

[a]	American Museum of Natural History (2000)
[b]	Wallestad (1975)
[c]	U.S. Environmental Protection Agency (1993)
[d]	Alaska Department of Fish and Game (2000)
[e]	Murie (1951)
[f]	Utah Department of Natural Resources, Division of Wildlife Resources (2000a,b)
[g]	Illinois Natural Resources Information Network (INRIN) (2000)
[h]	Arthur and Gates (1988)
[i]	Beyer and others (1994)
[j]	U.S. EPA (1999)

Herbivorous Birds

The species selected as the measurement receptor for this guild is the sage grouse (*Centrocercus urophasianus*). Sagebrush is an important food species at all stages of the life history of the sage grouse. For example, Wallstead (1975) determined that sagebrush comprised 62 percent of the total food volume of the sage grouse in a study of 299 sage grouse crop samples. The COPC daily dose for the sage grouse will be estimated assuming that 100 percent of its diet is terrestrial plants (F_{Pi} = 1.0).

Sage grouse range in weight from 1.6 kg to 2.9 kg (Wallestad 1975). A BW of 1.6 kg was used to calculate an FIR for the sage grouse so that COPC intakes would be based on a higher body weight-normalized ingestion rate. The FIR calculated was 0.41 kg WW/kg BW-day, and the WIR calculated was 0.051 L/kg BW-d (Nagy 1987, as presented in U.S. EPA 1993). No information on soil in the sage grouse diet was available, so an SIR of 0.0046 kg DW/ kg BW-d was calculated based on the wild turkey as a surrogate. The reported SIR for wild turkey is 9.3 percent of the diet (Beyer and others 1994).

Omnivorous Mammals

The species selected as the measurement receptor for the omnivorous mammal guild is the deer mouse (*Peromyscus maniculatus*). Deer mice are omnivorous and highly opportunistic, which leads to substantial regional and seasonal variation in their diet. The deer mouse diet is comprised largely of arthropods and seeds (FEIS 1996); however, they will consume some green vegetation, roots, fruits, and fungi as available (Johnson 1961; Menhusen 1963; Whitaker 1966). The deer mouse is an important prey species for most predators including snakes, owls, mink, marten and other weasels, skunks, bobcat, domestic cat, coyote, foxes, and ringtail (Maser and others 1981).

Under the “equal” diet scenario, the COPC daily dose for the deer mouse will be estimated assuming equal portions of the diet is made up of terrestrial invertebrates and terrestrial plants ($F_{Ai/Pi}$ = 0.5). The evaluation of an “exclusive” diet will identify pathway-specific hazard for omnivorous mammals.

Average weights of adult deer mice reported by U.S. EPA (1993) range from 0.0148 kg to 0.0223 kg (U.S. EPA 1993). A BW of 0.148 kg was used to estimate an FIR for the deer mouse so COPC intakes are maximized (based on a BW-normalized FIR). The FIR calculated was 0.87 kg WW/kg BW-d, and the WIR calculated was 0.151 L/kg BW-d (Nagy 1987, as presented in U.S. EPA 1993). An SIR of 0.00405 kg DW/kg BW-d was calculated based on 2 percent of the deer mouse’s daily FIR. The white-footed mouse soil ingestion rate was used as a surrogate for the deer mouse (Beyer and others 1994).

Insectivorous Birds

The American robin (*Turdus migratorius*) was selected as the measurement receptor for the insectivorous bird guild. Robins feed by hopping along the ground looking for invertebrates (which comprise approximately 40 percent of their diet) or searching shrubs and low tree branches for berries and insects (U.S. EPA 1993; CWS 2000). Natural predators of the American robin include raptors and bobcats (CWS 2000).

Under the "equal" diet scenario, the COPC daily dose for insectivorous birds will be estimated assuming equal portions of the Amercian robin's diet is made up of terrestrial invertebrates and terrestrial vegetation ($F_{Ai/Pi} = 0.5$). The "exclusive" diet scenario will also be evaluated to identify the significance of each of these exposure pathways.

U.S. EPA (1999) recommends using a BW of 0.080 kg to calculate a food ingestion rate for the American robin. This value is near the low end of BW values reported by U.S. EPA 1993. Based on the allometric equation for passerines developed by Nagy (1987), the FIR_{DW} is 0.94 kg WW/kg BW-d. A WIR equal to 0.1376 L/kg BW-d was calculated (U.S. EPA 1993; Nagy 1987). An SIR equal to 0.0213 kg DW/kg BW-d was calculated, based on dietary information in Beyer and others (1994).

Carnivorous Mammals

The species selected as the measurement receptor for this guild is the coyote (*Canis latrans*). The primary prey items of the coyote are small mammals; however, coyotes are opportunistic and will eat other available food items such as fruits and berries (Bekhoff 1977). The coyote has also been observed to hunt with other coyotes and kill young or weakened large mammals such as white-tailed deer and elk, especially in winter (Gese and Groth 1995; NGPC 2000). Great horned owls, bald and golden eagles, bears, and wolves have been known to prey upon coyotes (ADF&G 2000).

Under the "equal" diet scenario, the COPC daily dose for the coyote will be estimated assuming equal portions of the diet is composed of (1) herbivorous mammals, (2) omnivorous mammals, (3) terrestrial invertebrates, and (4) terrestrial plants ($F_{Ai/Pi} = 0.25$), as recommended by U.S. EPA (1999). An "exclusive" diet scenario will be conducted to evaluate the exposure potential associated with each dietary pathway.

Coyotes range in weight from 10 kg to 15 kg (NGPC 2000a; ADF&G 2000). Based on the allometric equation developed for carnivores by Nagy (1987), a 10 kg animal would ingest 0.15 kg WW food/kg BW-d. This value is fairly comparable to the site-specific FIR_{WW} of 0.07 kg WW/kg BW-d calculated by Dr. Bob Crabtree of Yellowstone Ecological Studies for coyotes inhabiting Yellowstone National Park (Crabtree 2000). The Nagy (1987) allometric equation for estimating WIR was used to estimate a coyote WIR equal to 0.079 L/kg BW-d (U.S. EPA 1993). A soil ingestion rate of 2.8 percent reported by Beyer and others (1994 for the red fox was used as a surrogate for the coyote, resulting in an estimate of an SIR equal to 0.00037 kg DW/kg BW-d.

Carnivorous Birds

The species selected as the measurement receptor for the carnivorous bird or raptor guild is the red-tailed hawk (*Buteo jamaicensis*). Red-tailed hawks feed mainly on small mammals, but will also eat birds, reptiles, and some insects (FEIS 1996; DeGraaf and others 1991; Dubois and others 1987; Palmer 1988). Natural predators of the red-tailed hawk include other raptors, coyotes, bobcats, crows, and skunks (FEIS 1996).

Under the "equal" diet scenario, the COPC daily dose for the red-tailed hawk will be estimated assuming equal portions of its diet is made up of (1) herbivorous mammals, (2) herbivorous birds, (3) omnivorous mammals, (4) omnivorous birds, and (5) terrestrial invertebrates (F_{Pi} = 0.20). Although a portion of the red-tailed hawk's diet may include reptiles, such as snakes and lizards, the data available on COPC uptake in reptiles (i.e., biotransfer and toxicity data) is limited. Thus, reptiles will not be included in the evaluation of COPC daily dose for the red-tailed hawk. An "exclusive" diet scenario will also be evaluated for the red-tailed hawk to identify dietary pathways that are driving risk.

Adult red-tailed hawk weights in the literature range from 0.96 kg to 1.24 kg (U.S. EPA 1993). Allometric equations were used to estimate food and water ingestion rates (U.S. EPA 1993). The lower number of the weight range was chosen, so that the higher ingestion rate would be used. The FIR calculated was 0.18 kg WW/kg BW-d, and the WIR calculated was 0.060 L/kg BW-d (U.S. EPA 1993). The soil ingestion rate for the red-tailed hawk is 0.00078 kg DW/kg BW-d (based on the relationship between FIR and SIR presented in U.S. EPA 1999).

Montane Habitat

The natural history information and values used in the daily dose equation for the receptor in each guild for the montane food web are discussed below.

Herbivorous Mammals

The elk (*Cervus elaphus*) was selected as the representative measurement receptor for the herbivorous mammal guild. Elk typically exhibit a browsing feeding strategy, which enables them to seek food over large areas of land throughout the day. Their foraging strategy may potentially put them in contact more often with contaminated food items and soil. Elk will begin feeding in the morning and continue for two or three hours (Skovlin 1982). After ruminating for most of the late morning and early afternoon, elk will again feed for two or three hours before sunset (Skovlin 1982). Skovlin (1982) also states that feeding, ruminating, and resting consume 90 percent of an elk's daily activity. While young, old, or weak individuals are usually targeted by predators, healthy adults may also be taken by packs of wolves and coyotes.

The COPC daily dose for the elk will be estimated in the ERA assuming that 100 percent of its diet is terrestrial plants (F_{Pi} = 1.0).

Murie (1951) calculated the average weight of an elk cow at 236 kg (520 lbs). This appears to be an informally agreed upon weight for an elk cow since it has been used and reported in several places (Flook 1970; Moen 1973; and Nelson and others 1982). The average bull weighs approximately 320 kg (Murie 1951). However, since food and water ingestion rates found in the literature for the elk are suspect (measured in captivity), allometric equations were used to estimate these values (Nagy 1987, as presented in U.S. EPA 1993). Based on a weight of 236 kg, an FIR of 0.16 kg WW/kg BW-d was calculated. A WIR of 0.054 L/kg BW-d was also determined. The soil ingestion rate is estimated to equal 0.00039 kg DW/kg BW-d, based on 2 percent of the elk diet (Beyer and others 1994).

Herbivorous Birds

The blue grouse (*Dendragapus obscurus*) was selected as the representative measurement receptor for the herbivorous bird guild. The diet of the blue grouse varies with season. Grouse generally browse for their food among the forested stands that they inhabit. In winter, up to 95 percent of the blue grouse diet consists of conifer needles and buds (UDWR 2000a) which are readily available and abundant for consumption throughout the winter months. In summer, the diet becomes comprised of green vegetation, seeds, buds, berries and insects (UDWR 2000a). Blue grouse may be taken by several different natural predators. In the state of Utah, predators of the blue grouse include bobcat, mountain lion, coyote, red fox, and raptors.

The COPC daily dose for the blue grouse will be estimated in the ERA assuming that 100 percent of its diet is terrestrial plants (F_{Pi} = 1.0).

Blue grouse range in weights from 1,273 grams for a male to 839 grams for a female (UDWR 2000a). Since food and media ingestion rates for the blue grouse are currently unknown, allometric equations were used to estimate these values (U.S. EPA 1993). The lower number of the weight range was chosen, so that the higher ingestion rate would be used. The FIR calculated was 0.59 kg WW/kg BW-d, and the WIR calculated was 0.054 L/kg BW-d (U.S. EPA 1993). The soil ingestion rate is 0.0049 kg DW/kg BW-d; the wild turkey was used as a surrogate for the soil ingestion rate because of similar feeding habits. The reported soil ingestion rate for wild turkey is 9.3 percent of the diet (Beyer and others 1994).

Omnivorous Mammals

The species selected as the representative measurement receptor for this guild is the deer mouse (*Peromyscus maniculatus*). The identification of BW and food and media ingestion rates are discussed above for the shrub-scrub food web.

Omnivorous Birds

The chukar (*Alectoris chukar*) was selected as the representative measurement receptor for this guild. Although adults eat mostly vegetation, young chukar feed on a high proportion of insects (FEIS 1996), which should be accounted for in the exposure assessment because young are more susceptible to toxicants and would be targeted by predators. Adult chukar will also feed on numerous insects during the summer months and rely heavily on new growth cheat grass in the winter (UDWR 2000a). Predators of the chukar could include coyote, bobcat, foxes, skunks, badger, raccoon, mountain lion, coati, snakes, and many raptors (Bohl 1957).

Under the “equal” diet scenario, the COPC daily dose for the chukar will be estimated assuming equal portions of the diet is made up of terrestrial invertebrates and terrestrial vegetation ($F_{Ai/Pi}$ = 0.5). An “exclusive” diet scenario will also be evaluated to identify pathways that are driving risk.

Body weights of chukar average about 0.6 kg (20 ounces) (UDWR 2000b). Since ingestion rates for the chukar are currently unknown, these values were estimated using allometric equations (Nagy 1987, as presented in U.S. EPA 1993). The FIR calculated was 0.32 kg WW/kg BW-d, and the WIR calculated was 0.070 L/kg BW-d (U.S. EPA 1993). The soil ingestion rate is 0.0070 kg DW/kg BW-d. The American robin was used as a surrogate for the soil ingestion rate because of similar feeding habits. The reported soil ingestion rate for American robin in U.S. EPA (1999) is 10 percent of the diet.

Carnivorous Mammals

The species selected as the representative measurement receptor for this guild is the coyote (*Canis latrans*). The identification of BW and food and media ingestion rates is discussed above for the shrub-scrub food web.

Carnivorous Birds

The species selected as the representative measurement receptor for this guild is the red-tailed hawk (*Buteo jamaicensis*). The identification of BW and food and media ingestion rates is discussed above for the shrub-scrub food web.

Aquatic Food Web

The natural history information and values used in the daily dose equation for the receptor in each guild for the aquatic food web are discussed below.

Herbivorous Birds

The species selected as the representative measurement receptor for this guild is the northern pintail (*Anas acuta*). Pintails are surface feeders of mostly aquatic vegetation (Bellrose 1980). Natural predators of the pintail include skunks, magpies, gulls, ground squirrels, coyotes, foxes, raccoons, and badgers (Bellrose 1980).

The COPC daily dose for the northern pintail will be estimated in the ERA assuming that 100 percent of its diet is aquatic plants (F_{Pi} = 1.0).

The average weight of a pintail ranges from 0.9 kg to 1.1 kg (INRIN 2000). Since ingestion rates for the Northern pintail are currently unknown, allometric equations developed by Nagy (1987) were used to estimate these values. The lower number of the weight range was chosen, so that the higher ingestion rate would be used. The FIR calculated was 0.50 kg WW/kg BW-d, and the WIR calculated was 0.061 L/kg BW-day (U.S. EPA 1993). The soil ingestion rate is 0.0012 kg DW /kg BW-d, based on similar feeding habits of the blue-winged teal. The reported soil ingestion rate for blue-winged teal is less than 2.0 percent of the diet (Beyer and others 1994).

Omnivorous Mammals

The species selected as the representative measurement receptor for this guild is the muskrat (*Ondatra zibethicus*). Muskrats prefer habitat with dense emergent aquatic vegetation that is surrounded by herbaceous terrestrial vegetation (FEIS 1996). Although they feed mostly on vegetation, they will occasionally feed on frogs, crustaceans, dead birds, and fish (Perry 1982). Coyotes, raptors, alligators, bobcats, and carnivorous fishes, turtles, snakes, and frogs are all predators of the muskrat.

Under the "equal" diet scenario, the COPC daily dose for the muskrat will be estimated assuming equal portions of the diet is made up of aquatic invertebrates and aquatic vegetation ($F_{Ai/Pi}$ = 0.5). While the muskrat diet may occasionally consist of amphibians (frogs), dead birds, and fish (Perry 1982), these food items will not be included in the evaluation of COPC daily dose for the muskrat as they are neither a major nor consistent portion of the muskrat diet. An "exclusive" diet scenario will also be evaluated to identify which dietary pathway is driving risk.

The weight range of muskrats cited in the U.S. EPA's *Wildlife Factors Handbook* is 0.837 kg to 1.480 kg (U.S. EPA 1993). Based on the allometric equation for omnivores (Nagy 1987) and a BW of 0.837 kg the FIR calculated was 0.09 kg WW/kg BW-d, and the WIR calculated was 0.101 L/kg BW-d (U.S. EPA 1993). The sediment ingestion rate is 0.00193 kg DW/kg BW-d (U.S. EPA 1993), assuming sediment constitutes 9.4 percent of the muskrat's daily intake. The raccoon's soil ingestion rate was used as a surrogate for the muskrat (Beyer and others 1994).

Omnivorous Aquatic Birds

The species selected as the representative measurement receptor for this guild is the mallard (*Anas platyrhynchos*). Mallard ducks are surface feeders that tip into the water and use their bills to filter their food. Although mallards are chiefly vegetarian, feeding mostly on aquatic vegetation, seeds, grains and stems, they may also consume fish eggs, mollusks, and other invertebrates from the water (TPW 2000). The mallards diet will vary with season and local food abundance and availability. Because of the mallard's species abundance, they are a common food source for many predator species, such as coyotes, bobcats, or raptors.

Under the "equal" diet scenario, the COPC daily dose for the mallard duck will be estimated assuming aquatic invertebrates and aquatic plants make up equal portions of the diet ($F_{Ai/Pi} = 0.5$). An "exclusive" diet scenario will also be evaluated to identify the pathway driving risk for each COPC.

The mallard's BW will vary with age, sex, and time of year. A BW of 1.040 kg (U.S. EPA 1999) was identified. Allometric equations were used to calculate the food and water ingestion rates for the mallard (Nagy 1987 as presented in U.S. EPA 1993). The FIR was calculated to be 0.26 kg WW/kg BW-d. The water and sediment ingestion rates were calculated as 0.058 L/kg BW-d and 0.0019 kg DW/kg BW-d, respectively. The soil ingestion rate is based on information presented in Beyer and others (1996).

Piscivorous Birds

The species selected as the representative measurement receptor for this guild is the great blue heron (*Ardea herodias*). The great blue heron's diet consists primarily of fish, which it grabs with its long beak while standing or wading in shallow water. Although fish are its preferred prey item, the great blue heron will also eat amphibians, reptiles, crustaceans, insects, small birds, and mammals (Alexander 1977).

Under the "equal" diet scenario, the COPC daily dose for the great blue heron will be estimated assuming equal portions of its diet is made up of aquatic invertebrates and fish ($F_{Pi} = 0.5$). Although a portion of the great blue heron's diet may include reptiles and amphibians, such as snakes and lizards, the data available on COPC uptake in reptiles and amphibians (i.e., biotransfer and toxicity data) is limited. Thus, reptiles will not be included in the evaluation of COPC daily dose for the great blue heron. Small mammals and birds will not be included in the estimation of COPC dose for the great blue heron because (1) the heron was selected for the piscivorous bird guild and (2) small mammals and birds are neither a major nor consistent portion of the heron diet. An "exclusive" diet scenario will also be evaluated in the ERA for the great blue heron in order to identify pathways that are driving risk.

The BWs of adult great blue herons range from 2.2 kg to 2.5 kg depending on sex, age and season (U.S. EPA 1993). Like most vertebrates, they lose weight prior to the breeding season and gain weight after. The lower number of the weight range was chosen, so that the higher ingestion rate would be used. Based on Nagy (1987), an FIR of 0.14 kg WW/kg BW-d and a WIR of 0.045 L/kg BW-d were calculated. In addition, a sediment ingestion rate of 0.00078 kg DW/kg BW-d was calculated (U.S. EPA 1999).

Carnivorous Mammals

The species selected as the representative measurement receptor for this guild is the coyote (*Canis latrans*). The identification of BW and food and media ingestion rates is discussed above for the shrub-scrub food web.

Carnivorous Birds

The species selected as the representative measurement receptor for this guild is the red-tailed hawk (*Buteo jamaicensis*). The identification of BW and food and media ingestion rates is discussed above for the shrub-scrub food web.

4.4 EXPOSURE ASSESSMENT FOR POLYCHLORINATED DIBENZO(P)DIOXINS AND POLYCHLORINATED DIBENZOFURANS, POLYCYCLIC AROMATIC HYDROCARBONS, POLYCHLORINATED BIPHENYLS, AND MERCURY

The following subsections discuss exposure assessment procedures specific to four classes of compounds that are recommended for automatic inclusion in all RCRA combustion risk assessments (U.S. EPA 1999). These compounds include PCDDs and PCDFs, polycyclic aromatic hydrocarbons (PAH), PCBs, and mercury.

4.4.1 Exposure Assessment for Polychlorinated Dibenzo(p)Dioxins and Polychlorinated Dibenzofurans

Scientific evidence indicates that low levels of PCDD and PCDF congeners, especially 2,3,7,8-substituted congeners, display dioxin-like toxicity and adversely effect ecological receptors (U.S. EPA 1993; Hodson and others 1992 as cited in U.S. EPA 1999). U.S. EPA recommends that the PCDD and PCDF congeners with chlorine molecules substituted in the 2,3,7, and 8 positions be included as COPCs in all RCRA combustion risk assessments. There are a total of 17 tetrachlorinated, pentachlorinated, hexachlorinated, heptachlorinated, and octachlorinated PCDDs and PCDFs that have chlorine molecules in the 2, 3, 7, and 8 positions.

The guidance provided in the SLERAP for assessing exposure to a COPC also applies generally to the exposure assessment for PCDDs and PCDFs. However, because congener-specific toxicity and bioaccumulation data are limited, U.S. EPA recommends that exposure of receptors to PCDDs and PCDFs be assessed using 2,3,7,8-TCDD toxicity equivalency factors (TEF) and 2,3,7,8-TCDD bioaccumulation equivalency factors (BEF) to convert the exposure media concentrations of individual congeners to a 2,3,7,8-TCDD toxicity equivalent (TEQ). This approach will be applied in the ERA.

The TEFs for these 17 congeners are listed in Table 4-3. A TEF value will be assigned to each congener relative to its toxicity in relation to 2,3,7,8-TCDD. Congener-specific emission rates and fate and transport properties will be used in the ERA to compute media-specific concentrations and estimate daily

TABLE 4-3

POLYCHLORINATED DIBENZO-P-DIOXIN AND DIBENZOFURAN CONGENERS TOXICITY EQUIVALENCY FACTORS (TEF) FOR FISH, MAMMALS, AND BIRDS

Dioxin and Furan Congeners	Receptor		
	Fish TEF	Mammal TEF	Bird TEF
2,3,7,8-TCDD	1.0	1.0	1.0
1,2,3,7,8-PCDD	1.0	1.0	1.0
1,2,3,4,7,8-HxCDD	0.1	0.1	0.05
1,2,3,6,7,8-HxCDD	0.1	0.1	0.01
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01	0.001
1,2,3,4,5,7,8,9-OCDD	0.0001	0.0001	0.0001
2,3,7,8-TCDF	0.1	0.1	1.0
1,2,3,7,8-PCDF	0.05	0.05	0.1
2,3,4,7,8-PCDF	0.5	0.5	1.0
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpDF	0.01	0.01	0.01
1,2,3,4,6,7,8,9-OCDF	0.0001	0.0001	0.0001

Notes:

HpCDD Heptachlorodibenzo(p)dioxin
HpCDF Heptachlorodibenzofuran
HxCDD Hexachlorodibenzo(p)dioxin
HxCDF Hexachlorodibenzofuran
OCDD Octachlorodibenzo(p)dioxin
OCDF Octachlorodibenzofuran
PCDD Pentachlorodibenzo(p)dioxin
PCDDs Polychlorinated dibenzo(p)dioxins
PCDF Pentachlorodibenzofuran
PCDFs Polychlorinated dibenzofurans
TCDF Tetrachlorodibenzofuran
TCDD Tetrachlorodibenzo(p)dioxin

Sources: U.S. EPA (1999) and Van den Berg and others (1998).

doses for guild measurement receptors. To characterize risk, the exposure media concentrations of individual congeners will be converted to a 2,3,7,8-TCDD TEQ by multiplying each concentration by the congener-specific TEF value corresponding to the particular measurement receptor being evaluated.

There are practical limitations with the available PCDD and PCDF emissions data. Some of the PCDD and PCDF emission rates are congener-specific (a separate value for each of the 17 2,3,7,8-substituted PCDDs and PCDFs), while the rest of the data only reports total isomer group information (that is, a value only for total 2,3,7,8-tetrachlorinated dibenzo(p)dioxins, 2,3,7,8-pentachlorinated dibenzo(p)dioxins, etc.). Therefore, for those furnaces and agents where congener-specific PCDD/PCDF data are available (whether actual or extrapolated), each 2,3,7,8-congener will be modeled individually until EELs are calculated. Then, these concentrations will be converted to 2,3,7,8-TCDD TEQ values for calculating risk (see Section 6.0).

For furnaces and agents where only total isomer group data are available (whether actual or extrapolated), the isomer group will be modeled by applying the total isomer group value to the congener that will result in the highest media concentration (as determined by a congener's physical/chemical properties and biotransfer factors presented in U.S. EPA (1999). Note that the TEFs are the same for all of the congeners with a given isomer group except for the pentachlorinated dibenzofurans; therefore, relative toxicity is not anticipated to significantly impact this procedure. As a conservative measure, the TEF for 2,3,4,7,8-PCDF will be used to complete the risk assessment in those cases where only total PCDF values are available. The TEFs are listed in Table 4-3.

4.4.1.1 Exposure Assessment for Community Measurement Receptors

In order to evaluate the exposure of community measurement receptors to PCDDs and PCDFs, congener-specific concentrations in the respective media to which a community is exposed will be converted to a 2,3,7,8-TCDD TEQ by multiplying the individual congener-specific media concentrations by the congener-specific TEFs for fish, then summing the results to obtain the TEQ, as follows:

$$\mathrm{TEQ} = \sum \left(C_{MI} \cdot \mathrm{TEF}_i \right)$$

where

TEQ	=	2,3,7,8-TCDD toxicity equivalence concentration (microgram per liter [µg/L; water] or microgram per kilogram [µg/kg; soil or sediment])
C_{MI}	=	Concentration of the ith congener in abiotic media (µg/L [water] or µg/kg [soil or sediment])
TEF_i	=	Toxicity equivalency factor (fish) for *i*th congener (unitless)

Risk to community measurement receptors will then be estimated by comparing the media-specific 2,3,7,8-TCDD TEQ to the corresponding media-specific toxicity benchmark for 2,3,7,8-TCDD. U.S. EPA assumes that TEFs for fish accurately reflect the relative toxicity of PCDD and PCDF congeners to all community receptors (U.S. EPA 1999).

4.4.1.2 Exposure Assessment for Mammalian and Avian Measurement Receptors

In order to evaluate the exposure of guild measurement receptors to PCDDs and PCDFs, congener-specific daily doses of all food items (e.g., media and plant and animal food items) ingested by a measurement receptor will be converted to a 2,3,7,8-TCDD TEQ daily dose (DD_{TEQ}). The congener-specific daily doses of food items ingested by a measurement receptor will be calculated using the general exposure assessment procedures presented in the SLERAP (including the use of congener-specific media concentrations, BCFs, and FCMs). However, the limited availability of congener-specific BCFs requires that media-to-receptor BCFs available for 2,3,7,8-TCDD be used in conjunction with congener-specific BEFs to obtain estimated congener-specific BCF values, using the following equation:

$$BCF_i = BCF_{TCDD} \cdot BEF_i$$

where

BCF_i	=	Media-to-animal or media-to-plant bioconcentration factor for ith congener (L/kg [water] or unitless [soil or sediment])
BCF_{TCDD}	=	Media-to-receptor BCF for 2,3,7,8-TCDD (L/kg [aquatic receptor] or unitless [soil and sediment receptor]
BEF_i	=	Bioaccumulation equivalency factor for ith congener (unitless)

Congener-specific BEFs were developed as measures of bioaccumulation potential relative to 2,3,7,8-TCDD. Estimated congener-specific BCFs calculated using this approach are provided in the SLERAP and will be used to assess exposure to PCDDs and PCDFs.

The daily dose of each PCDD and PCDF congener ingested by a mammalian or avian measurement receptor will then be multiplied by the congener-specific TEF that corresponds to that measurement receptor. The results for each particular measurement receptor will be summed to obtain the DD_{TEQ} for the measurement receptor, as indicated in the following equation:

$$DD_{TEQ} = \sum \left(DD_i \cdot TEF_{Receptor} \right)$$

where

DD_{TEQ}	=	2,3,7,8-TCDD TEQ daily dose (μg/kg BW/day)
DD_i	=	Daily dose of the ith congener (μg/kg BW/day)
$TEF_{Receptor}$	=	Toxicity equivalency factor (measurement receptor-specific (unitless)

Risk to each class-specific guild will then be estimated by comparing the DD_{TEQ} for each measurement receptor to the corresponding receptor-specific toxicity benchmark for 2,3,7,8-TCDD.

4.4.2 Exposure Assessment for Polycyclic Aromatic Hydrocarbons

PAHs are readily formed in combustion units by either (1) dechlorination of other PAHs present in the waste feed or emissions stream (such as dioxins), or (2) the reaction of simple aromatic compounds (benzene or toluene) present in the waste feed or emissions stream. PAHs are well known as the principal organic components of emissions from all combustion sources. Therefore, based on the toxicity and combustion chemistry of PAHs, U.S. EPA (1999) recommends that PAHs be evaluated in all combustion-related risk assessments.

The exposure of community and class-specific guild measurement receptors to individual PAHs will be conducted consistent with methods presented in Sections 4.1 and 4.2.

4.4.3 Exposure Assessment for Polychlorinated Biphenyls

Research on PCBs has revealed that some mildly chlorinated PCB congeners can have dioxin-like effects (U.S. EPA 1992; ATSDR 1995 as cited in U.S. EPA 1999). For example, the rings of coplanar PCBs, which are PCB congeners with four or more chlorine atoms with few substitutions in the ortho positions (2, 2', 6, or 6'), can rotate into the same plane if not blocked from rotation by ortho-substituted chlorine atoms. In this configuration, the shape of a PCB molecule is similar to the shape of a PCDF molecule and can react with the aryl hydrocarbon receptor to initiate the adverse effects of PCDDs and PCDFs (U.S. EPA 1999).

The HHRA (Tetra Tech 2002a) determined that the sampling data indicated the mixture of PCBs in stack gas emissions contained 0.5 percent or more PCF congeners with more than four chlorine atoms. Therefore, total PCB EELs will be estimated using the fate and transport properties of Aroclor 1254 (U.S. EPA 1999). Risk will be characterized by comparing the EELs to Aroclor 1254 TRVs.

Fourteen PCB congeners also present dioxin-like properties. For the exposure assessment for the dioxin-like PCBs, PCB TEF values will be applied to the congener-specific air concentrations and wet and dry deposition rates to determine 2,3,7,8-TCDD TEQ media concentrations. Fate and transport properties of Aroclor 1254 will also be used to estimate 2,3,7,8-TCDD TEQ daily doses (U.S. EPA 1999). Risk will be characterized by comparing the 2,3,7,8-TCDD values to 2,3,7,8-TCDD TRVs. Recommended TEFs for coplanar PCBs are presented in the SLERAP.

4.4.4 Exposure Assessment for Mercury

Because anthropogenic mercury releases are thought to be dominated on a national scale by industrial processes and combustion sources that release mercury into the atmosphere, U.S. EPA (1999) recommends that mercury be evaluated in all combustion-related risk assessments. To assess exposure of community and class-specific guild measurement receptors to mercury, guidance provided in Sections 4.1 and 4.2 will generally be followed. However, special consideration will be given when evaluating the various forms of mercury modeled to the point of exposure.

To evaluate exposure of water, sediment, and soil communities to mercury, species-specific concentrations of divalent mercury and methyl mercury, in the respective media to which the community is exposed, will be directly compared to toxicity benchmarks specific to those compounds. The species-specific media concentrations will be calculated using the methods presented in Section 4.2.3 and equations presented in Appendix C. Media-specific toxicity benchmarks for divalent and methyl mercury are provided in Appendix E.

To evaluate the exposure of mammalian and avian measurement receptors to mercury, both divalent and methyl mercury will be modeled as independent COPCs through the food webs. This assumes no methylation of divalent mercury to the methyl mercury form within organisms. Therefore, the daily doses of all food items (i.e., media, plants, and animals) ingested by a measurement receptor will be considered for both divalent and methyl mercury, and compared to the respective TRVs (see Appendix E). The daily doses of food items ingested by a measurement receptor will be calculated using the procedures presented in Section 4.2.